MAKING PRINTED CIRCUIT BOARDS – A DIFFERENT VIEW

John Case, GW4HWR*

Sooner or later most home constructors find the need to make their own pcbs, and will probably use the methods that are so often described in various magazine articles. Here are some ideas of a different method of making professional-looking boards, and details that enable some of the equipment required to be built at low cost.

FOR MOST OF US the first attempts to make a pcb involve taking a piece of copper laminate, cleaning it carefully by means of fine wire wool or a special abrasive rubber, and then putting on the foil pattern by means of an etch-resist pen. This is relatively quick but cannot produce the fine detail required by most modern circuits.

The next step would be to lay down the foil pattern by the use of rub-down transfers which form a good etch resist and also allow the pattern to be laid down with a fair degree of neatness and accuracy. This method is slow and requires considerable patience (a commodity usually found in home constructors), but when copying a foil pattern from a magazine the actual method of transferring the pattern is quite difficult.

After considerable work using either of the two techniques, the board is etched and, hopefully, a successful pcb is produced, but things do go wrong: eg the etch solution is exhausted or polluted, the etch resist comes off during etching or, worst of all, the circuit has been laid down as a mirror image. The board is useless but, more important, all of the time and work in preparation has been wasted.

The photographic method of preparing and making a pcb avoids most of the problems and is not nearly so difficult as many people believe. The process involves producing a positive transparency which is placed in contact with a photo-sensitive board and exposed to ultra-violet light (Uv). At the end of the exposure, the board is developed in a simple solution in which the exposed areas of the photo-resist material are washed away leaving the foil pattern covered in resist material. After washing in cold water the board is etched in the normal manner. If there is a mishap, as previously mentioned, or if components need to be added or connected in a different way, the original transparency can be modified and another board produced with very little extra work.

Most constructors are unable to make use of this process because they don't have a suitable Uv light source. Sunlight can be used, but it is slow and variable, so that it is almost impossible to judge the correct exposure. A Uv light box designed for the above and other applications can be built for about £15 (the cost of buying two average prepared boards) compared with about £60-£70 for an equivilant commercial unit, and is described fully later.

Producing the transparency – Method 1

Use rub-down transfers onto a polyester drafting sheet that is Uv clear – in other words, ultra-violet light will pass through it. I prefer to use sheets carrying a 0·1 by 0·1in graph matrix which makes it much easier to lay out the circuit, especially when designing your own; the graph pattern does not print when exposed to Uv. Drafting sheets are obtainable from a number of suppliers of pcb materials. The one I use most often is that sold by RS Components or their mail order connection Electromail. It appears rather expensive at about £6 for a pack of 20 A4 sheets, but a pack will provide a large number of transparencies. If drawing up your own circuit, lay it out from the component side of the board so that, when printing, the symbols will be against the photo-sensitive material. If a diagram from a book or magazine is being copied, it will be easier to copy the foil pattern by laying a piece of drafting sheet over the diagram, holding it in position with small pieces of pvc adhesive tape and rubbing down the transfers to cover the pattern below. When this is printed the symbols will be separated from the board by the thickness of the sheet and some undercutting by the Uv will take place. This will not matter except when very thin lines are being used, and a way to minimise the effect will be mentioned later.

When buying rub-down transfers it is important to obtain those which do not crack or pickup those pieces already laid down when other fresh items are being rubbed down. This latter effect can be most frustrating when a fairly high density pcb is being drawn up. I prefer transfers of a tougher plastic nature, such as Alfac, to those supplied by RS Components. These are obtainable in many different shapes and from most radio component retailers. The actual types used obviously depends on personal preferences and on the kind of circuit being produced. Those I use most commonly are shown fullsize in Fig 1 together with the Alfac reference number. Keep completed parts of the work covered as far as possible to prevent damage by the sticky backing of the transfer sheets.

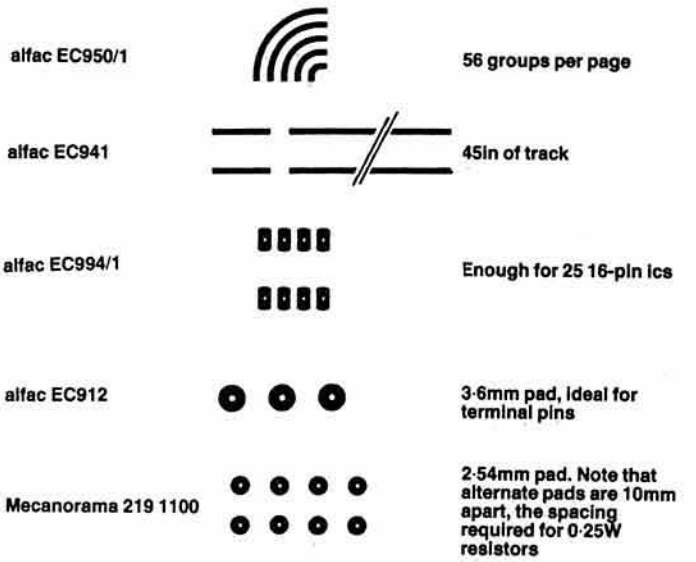
alfac EC950/1
56 groups per page
alfac EC941
45in of track
alfac EC994/1
Enough for 25 16-pin ics
alfac EC912
3·6mm pad, ideal for terminal pins
Mecanorama 219 1100
2·54mm pad. Note that alternate pads are 10mm apart, the spacing required for 0·25W resistors

Fig 1. A selection of transfers shown full-size

In addition to the transfers, pens with waterproof and opaque ink are very useful. Staedtler Lumocolor 313 (very fine) and 317 (medium) are very suitable and are obtainable from most office stationery retailers. The fine pen can often be used with a straight edge to lay down straight track and the outlines of large areas that need to be made opaque. It can also be very handy when small cracks and other damage need to be repaired; in spite of all the care you take, some damage will occur so just keep the patience going. The same pen is used to prevent the undercutting previously mentioned when the foil pattern is being traced from a print. This is done by reversing the completed drafting sheet and carefully covering the reverse of the thin tracks using the fine pen.

Other useful tools are a fine pointed knife or scapel and a typewriter rubber (in the form of a pencil). The knife is used to cut straight track and curved transfers (while still on the backing sheet) to appropriate length and for removing any transfer or ink incorrectly laid down. The rubber is excellent for cleaning up an area after corrections have been made with the knife. Keep rubbing down the pattern already laid down with the special backing provided, using the rounded end of a pencil. You will find

*2 Abbey Close, Tyrhiw, Taffswell, Mid-Glamorgan CF4 7RS.

that a medium soft pencil is better for rubbing down the transfers than a ball point pen which tends to split them. Large areas can be filled in using the medium pen and if difficulty is met in getting completely opaque areas, again turn the sheet over and repeat the fill-in on the reverse side of the transparency. When the foil pattern is complete, mark any terminal pins, eg IN, OP, LO etc, using alpha-numeric rub down transfers (Letraset). This helps the process of putting in the components at a later date and also makes life easier when connecting up. Also add your callsign, making sure that it will be the correct way round when printed. This is not just pride, it also serves as an indicator when placing the transparency on to the copper laminate. Now hold the completed positive up to the light or, better, lay it on an ordinary light box, if you have one, and examine it carefully for cracks in the pattern and repair as necessary. If you intend making a number of boards to the same pattern, it would be a good idea to make a more permanent copy as described later.

Hold the transparency so that the foil pattern is the correct way round, ie your callsign is right and lay the face you are looking at down onto the glass of the Uv box. Take a small piece (off-cut) of photo-resist pcb and peel off the protective coating; avoid bright sunlight, normal daylight will not harm the coating. Lay the piece down on the transparency so that it covers a dense portion of the pattern and, of course, with the emulsion side down. Now make a test exposure, usually about 5-6min is necessary when using the light box described and RS drafting sheet. Develop in a solution of sodium hydroxide made by dissolving 25grams of caustic soda in one litre of water. Any friendly chemist will make this up for you, or if you wish to make it yourself, ask for industrial caustic soda and dissolve 25 grams, about four heaped teaspoons, in one litre of cold water. Take great care, the crystals are very corrosive. Replace the lid of the container tightly as the crystals are deliquescent (they absorb water) and the whole lot will become solid. The solution is mildly corrosive, so keep it off your hands and clothes. Use plenty of water to remove any that gets in the wrong places. After about 30s the image should appear and the etch resist will be washed from the clean areas. When the copper appears to be clear, wash the piece thoroughly in cold water, gentle rubbing with the fingers during washing helps to remove any redundant resist. Now examine the test piece carefully. If the pattern of the grid is clearly visible, the exposure was too short although small patches of faint grid will be etched away in the ferric chloride solution. If the strips on the board appear to be thinner than on the transparency, the exposure was too long.

Cut a piece of photo-resist pcb about 5mm bigger-all-round than the transparency, drill a small hole as close to one corner as possible and remove any burr. Strip off the protective coating from the board and carefully align the transparency in the centre of the photo-resist side, making sure that it is the correct way round. Two small pieces of Sellotape may be used to hold the two together, then lay the combination on the glass of the Uv box so that the transparency is against the glass. Time the exposure carefully.

Develop, and wash very thoroughly as before. It is important to keep the board wet until it is put into the etch bath, otherwise resist residue will dry on the surface and prevent correct etching. If the etch bath is deep, tie a piece of pvc "hook up" wire through the hole to make it easy to remove the board from the etching solution. Return the sodium hydroxide to the bottle, as it can be re-used many times.

Method 2. Photo-copy

This is suitable for foil patterns published in books and magazines. If the design is not exactly right for your needs, minor modifications may be made by whitening out the areas to be changed with type-writer correction fluid, and replaced with transfers or pen as previously described. If you do not wish to deface the original (it may not be yours) have a photo-copy made and modify the copy. When satisfied that the pattern is that required, have another copy made but this time ask for a transparency. This is the same as any other copy except that it is made on transparent "paper". Most professional copiers will provide such a copy, but the price is a bit more than the standard. Don't be tempted to print this on photo-sensitive board; it is not dense enough and the resulting pcb will be patchy at the best. A good and very durable copy is now made using Reprofine film. This is an orange-coloured film that can be handled for short periods in ordinary room light, but in the long term is stored under light proof conditions like any other photographic film. When the film is exposed to Uv light and developed in a special solution, the exposed areas become clear and the unexposed parts turn black. Cut a small piece of film about 1 by 2in and return the remaining film to its envelope. Lay the photocopy on the glass plate of the Uv box and put the piece of film over a densely-populated part of the pattern, close the lid and expose for about 2-3min. The developer can be applied by means of a small wad of cotton-wool. Wipe *both* sides gently.

The pattern will appear almost immediately. There is no advantage in prolonging the development, wash the piece carefully in cold water. Hold the film up to the light and examine carefully. The clear areas should be clear, and the black a deep purple. If the clear areas are muddy the exposure was too short, and if the black parts only moderately dark or patchy the exposure was too long. When the correct exposure is found it should be remembered as it will be constant for other transparent copies when using your own light box. If during the washing process the print comes off, don't worry, as this is only the top layer and gentle rubbing with the fingers will remove the rest of it. If you are careful and sparing with the wash, the problem will not occur and a denser copy will result. The whole diagram can now be printed using a piece of film a little larger than the foil pattern. After washing, pin one corner to the edge of a shelf and allow to dry or speed up the process with the aid of a hair dryer. When dry, the transparency can be used to print the photo-sensitive pcb; an exposure of about 3min would be necessary, although it would be a good idea to make a test using a small piece of board. Again the time will be constant for a particular type of pcb.

If minor alterations need to be made in the photographic copy they can be done by carefully scraping off the black coating with the scalpel, but remember that the pattern is now on both sides of the film, then put in the new pattern by means of transfers or the Lumocolor pens. As already mentioned, the Reprofine copy is very durable and if a number of identical boards are to be made it is a good idea to make a copy of a pattern laid out on drafting film, as this is very easily damaged. It must be stressed that printing with Reprofine film is very simple and there are none of the problems that are met with ordinary photographic processing; in fact, it is easier to make a copy than to produce the pcb! One problem does occur, however; the film and developer are easy to obtain but in rather large and expensive quantities. Instagraphic Products Ltd will supply a pack of 10 A4 sheets of film and a one litre bottle of developer for about £25. This quantity will make 40 to 50 medium-size pcb foil patterns. I would suggest that a number of people should get together to buy a pack and to divide it up. The same firm will also supply an excellent range of rub-down transfers and drafting film. They will provide a full catalogue free of charge, when writing, request also the Mecanorma catalogue of artwork aids.

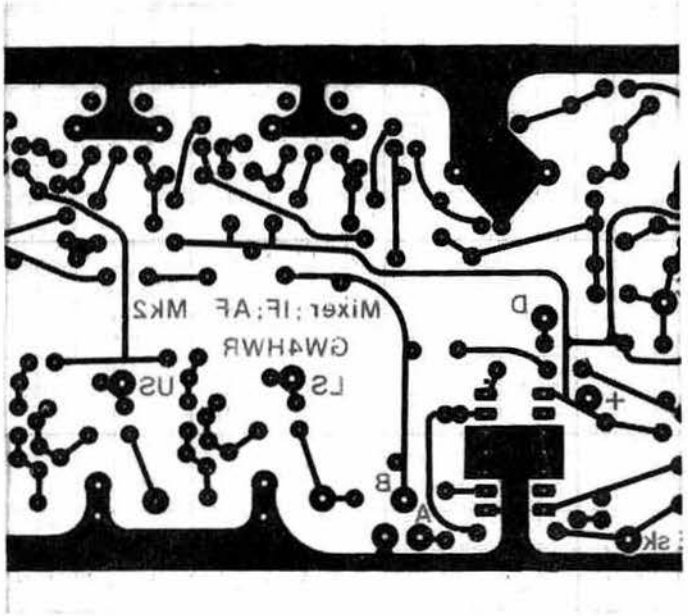

Fig 2. A finished transparency on drafting film. The side shown should be in contact with the sensitive side of the pcb material. The legend etc are mirror image and are on the reverse side

Method 3. Copy on to drafting sheet

This is the easiest way of making a transparency from a printed foil pattern, but requires the facility of being able to put a piece of A4 drafting film into the copier. Put the drafting paper on to the top of the paper in the magazine and then print in the normal way. An excellent copy will result which can be printed in the Uv light box on to photo-sensitive pcb.

Double-sided boards

These are no problem when the Uv process is used. Take a strip of pcb material a little longer then the foil pattern and about 0·25in wide. Use small pieces of Sellotape to attach one transparency to the strip so that it is just outside the pattern area. Hold the other to the other side of the strip and adjust the position until the correct holes coincide, then fix to the strip. Remove the protective coating from both sides of the pcb and slide it in between the two transparencies. Again fix with tape and expose both sides to the Uv light in turn.

The light box

This is a very simple device requiring very little skill other than the ability to make a wooden box. The dimensions given are not very critical and may be modified to accommodate a large choke than the one quoted. The window area should not be made any bigger as it would then be possible to put boards and film in a position of reduced illumination.

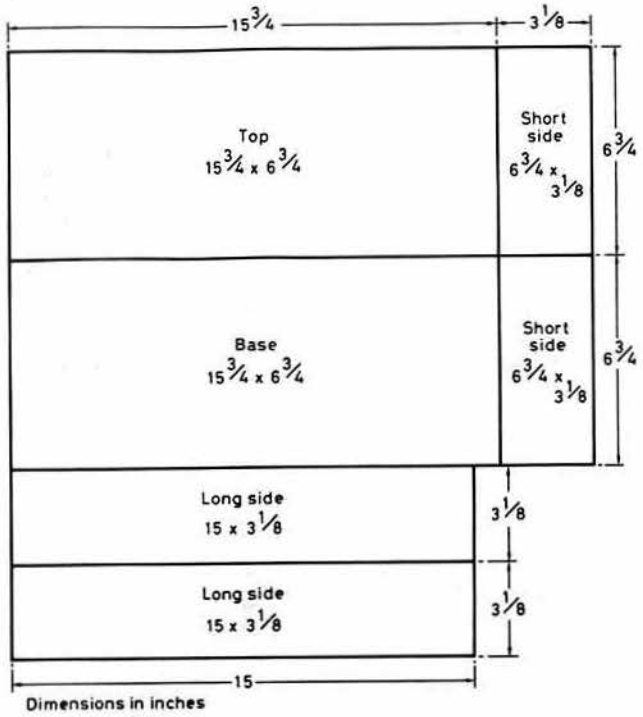

Fig 3. Cutting plan. Note: dimensions are only correct if material is ⅜in thick

Many would-be cabinet makers avoid making boxes because of the difficulty of making the top fit the bottom. This problem can be avoided and a top produced that will fit, even if the box itself is rather mis-shapen. Top and bottom are made up in one piece then the top is sawn off. If you are lucky you may be able to convince your diy supplier (especially if he is a builders merchant) to cut the six pieces for you. If not, a piece of ⅜in (actual dimension) ply about 21 by 20in will be required. Cut the pieces as accurately as possible and clean up the edges with a plane. Mark the top edge of all four side pieces and then draw a line exactly 0·5in below the top edge. Also draw a line on the outer surface of the top and bottom, ⅜in from each edge which will act as a guide for the nails. Use a good woodworking glue. (I prefer Cascamite made with a little less water than

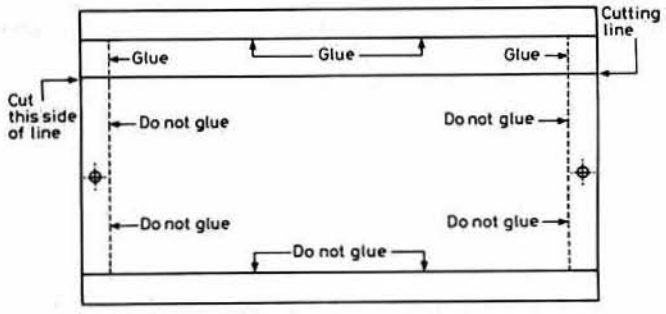

Fig 4. Showing the non-glued edges

recommended), and 0·75in panel pins. Note: 1in pins are too long and will foul the saw when the top is sawn off later. Starting with the top, drive pins (in the centre of the ⅜in strips) through the long and short edges so that they just emerge on the other side. a spacing of 3in is about right. Do the same with the bottom.

NOTE. The lower part of one short side must not be glued (see Fig 4) as this piece must be removable to allow access to the tubes and starters etc.

Coat the top of one short side with glue, align the top with the side and drive in the nails. Before the heads disappear, check the alignment and if not correct withdraw the nail with pincers or pliers and repeat moving the nail a little to one side of the first position. When satisfied that all is correct, hammer the nails right in. Next coat the top edge of one long side, bring the top and short side into position, making sure that there is no gap between long and short sides, and drive the nails in. Now coat the top edge of the second short side and top 0·5in only of the two long sides and nail. Do not drive the nails in the lower part of the short side all the way. Leave ⅛in protruding so that they can be removed later. If you have not already done so, nail the other corners but *do not put nails closer than 0·25in of the line drawn 0·5in from the top.*

Now glue and nail the bottom. Once again leave the nails in the unglued short side protruding. Wipe off any excess glue with a damp cloth. The next job is probably the hardest part. Leave the glue to set; at least overnight! When dry, tidy up the edges with the plane or rasp and sandpaper. Now cut off the top. Hold the box as securely as possible. If you have a Workmate-type bench it should be no problem, or perhaps you could borrow one for this task. If not, hold the box as tightly as possible. Starting at the short end which is not glued at the bottom, saw just to one side of the line drawn 0·5in from the top edge. It is now ⅞in from the top because of the top board. Try to keep the line just visible and saw very slightly below it so that the inside depth of the top is a full 0·5in deep. Turn the box as necessary and continue sawing. If it is necessary to clamp across the depth of the box make sure that the gap already sawn is not squeezed together. Put in pieces of card or pcb to keep the gap open and so prevent the saw jamming. Take special care when the cut is almost complete, hold the top so that as the last bit is sawn it does not break away. Clean up all the edges with plane, rasp or sander.

You should now have a box with a fitting lid. Using a small drill (2mm or No 44), drill holes in the centre edges of the unglued short end; right into the sides. See Fig 4. Remove the nails that are sticking out and gently tape the side piece out.

The hinges are let into both top and bottom so that there is almost no gap when the lid is closed. The recess can be cut with a coarse file. Drill a 0·25in hole in the right-hand short side about 1in from front and bottom for the mains lead. The mains switch should now be fitted about 1·5in from the right-hand edge and 1in from the top edge. The exact position and size of hole will depend on the type of switch chosen. Make sure that it is a mains type, preferably double pole and, if possible, with a built-in neon indicator to show when the light is on. Alternatively you could use a separate indicator.

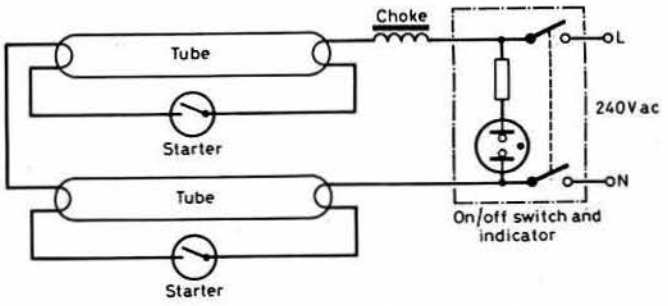

Fig 5. Showing how two 8W tubes are connected to a common ballast choke 13W

The choke, starter lamp holders and lamp holders (or Terry clips) can now be fitted in accordance with the dimensions given in Fig 6. If Terry clips are to be used to hold the tubes rather than batten type tube holders, the centre of the tubes should be about 0·75in above the floor of the box. If less than this, use spacers under the Terry clips. I used 0BA full nuts for this purpose. Check that the tubes together with their end connectors will fit, and then remove all parts from the box. Cut a piece of kitchen foil the same size as the bottom of the box, try to keep it free from creases and using dilute glue or wallpaper paste, glue the foil to the bottom of the box with the shiny side facing up. Smooth out as far as possible and press the foil over the component fixing holes with a finger to locate the screws

later. While the glue is drying locate the components in their approximate positions and wire up as shown in Fig 6. It is much easier to connect up this way as space inside the box is rather limited. Use mains-grade insulated wire. The inners of mains flexible cable would be in order. When the glue is dry re-fix the components in the box keeping the wires in the corners as far as possible. Fix the on/off switch and connect a 1·5m length of two-core mains lead. Connect the output side of the switch to the choke etc. Use a small cable clamp to prevent strain on the switch when the cord is pulled. A 13A plug top fitted with a *3A fuse* completes the electrical installation which may now be tested. Note: the output from the 8W tubes is relatively harmless but do not leave switched on without the top in position and do not look closely at the lamps for more than a few seconds.

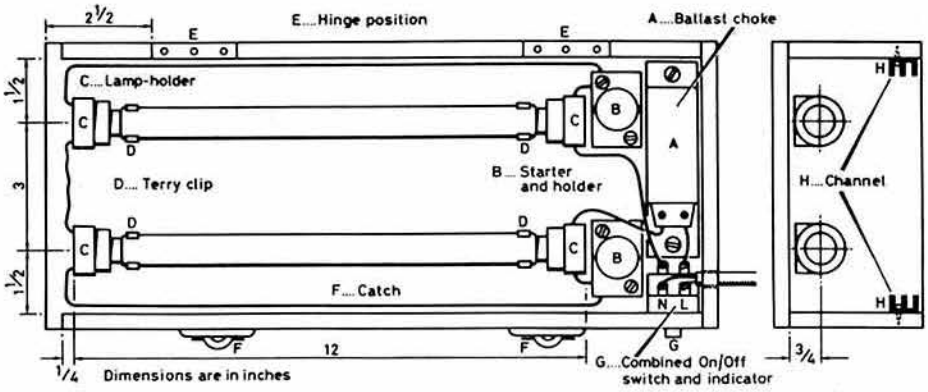

Fig 6. Layout of components and critical position of tubes

To get a professional finish the box can now be covered. A local bookbinder can usually supply thin book cloth which is ideal. Use carpenters glue and allow an inch to turn in at the edges.

Enlarge the two holes in the small free end to accommodate 0·75in self-tapping screws. Fit the hinges and small catches so that there are no undue gaps between top and bottom. Cut two pieces of plastic sliding door channel to fit inside the long edge of the box. Screw and glue the channels so that they are almost level with the top. The ⅜in screws should be in the lower slot.

Use a steel rule to measure the distance between the bottoms of opposite pieces of channel. Check at both ends and in the centre and use the smallest measurement. Measure the length between the short ends and obtain a piece of 3mm or 4mm glass with these dimensions. Measure very carefully and reduce the width by about 1mm to make sure that it will slide into the top grove of the channel. Mask the glass as shown in Fig 8 and paint areas A and B using black paint. When dry, remove the tape. Slide the glass, painted side down, into the top slot of the channel and fix the loose end into position.

Finally cut a piece of soft 0·75in foam to fit inside the lid and hold in position with a few spots of glue. The foam acts as a pressure pad to hold the transparencies and film/pcb together. The box is now complete. □

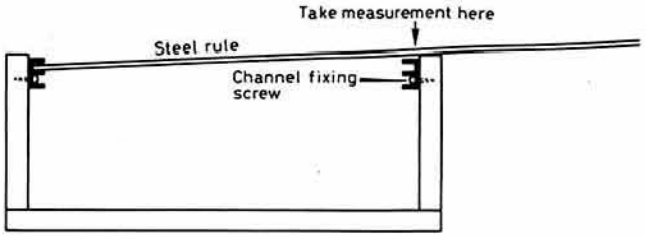

Fig 7. Measuring the required width of glass

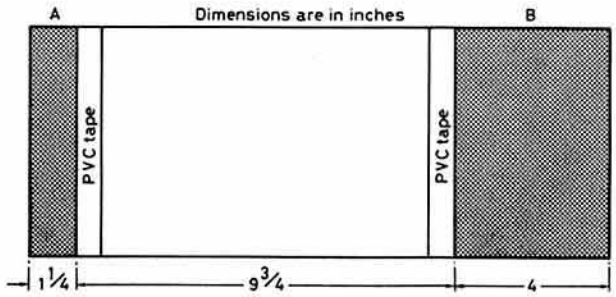

Fig 8. Masking the glass and area to be painted

Materials and useful addresses

Drafting film and rub-down transfers: RS Components (Electromail), Instagraphic Products Ltd, or Cirkit.

Reprofine positive film and Reprofine developer: Instagraphic Products Ltd.
Instagraphic Products Ltd. Ashfield Industrial Estate, Low Hall Road, Horsforth, Leeds LS18 4EF.
Electromail, PO Box 33, Corby, Northants NN17 9EL.
3M: Graphic Arts Group/3M, 3M United Kingdom PLC, 3M House, PO Box 1, Bracknell, Berkshire RG12 1JU.
This last address is very useful. Once you have a Uv light source, lots of other processes become possible. Fancy labels is one. Write asking for details of Photolabels. They will give you details of local stockists and will probably send some samples and very nice illustrations of the type of label you can produce.

Light box parts

Two 12in 8W Uv tubes TL @ £2.45 £5.90
Two starters @ 35p 70p
Two starter holders @ 40p 80p
One 13W choke (Optima) £2.60

All above from electrical wholesaler. Prices quoted are those paid by the author and do not include VAT.

Four Terry clips @ 12p 48p
One piece of book cloth 1 by 1·5m £1
One piece of 0·75in foam 30 by 12in 50p
⅜in ply, 0·75in panel pins, hinges and catches all in junk box

TECHNICAL FEEDBACK

"A QRP transceiver for 1.8MHz", S E Hunt, G3TXQ. *Radcom* September 1987, p654.

In response to requests from constructors who wish to move the frequency to 3·5MHz, the author has supplied the following revised component values:

C27, 29 220pF silver mica.
C28 18pF silver mica.
C49 56pF silver mica.
L1,2 30t on T68-2 core tapped at 4t from ground.
L5 30t on T68-2 core tapped at 7t from ground.
Remove C26 and C30

Coverage will be approximately 3·6–3·8MHz.

A number of correspondents have had trouble in finding cores for T1,2 and T3,4. Alternatives to those specified can be obtained from Electrovalue Ltd, these are:

T1,2 Electrovalue Part No.K0038X830 ring core.
T3,4 Electrovalue Part No.A0004X030 twin hole bead.

"Reduction of rf breakthrough from the BBC microcomputer", J C Worsnop, G4BAO. *Rad Com* December 1987, p906.

Mr R Broadbent, G3AAJ, secretary/treasurer of Amsat-UK and editor of *Oscar News*, has pointed out that details of the "professional" zinc spraying, and many of the modifications in the article were included in a note available to Amsat members published in 1983. Many of the hints and tips were passed to me via the amateur radio "grapevine", and I was unaware of the published note at time of preparation of the article. He is not suggesting that the article should not have been published, and in fact has included the following extra information which may be of interest: "The price for the Decco spray zinc process is £20 plus VAT; the company will mask the cases, and refurbish them after spraying". He agrees that the main sources of radiation after case spraying are the connecting leads. In the original note it was stated that the plug top would not pass through the hole in the case, I still maintain that mine did!

G4BAO